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AN EVALUATION OF COMNAVSURFPAC's
INFORMATION ENGINEERING INITIATIVE FOR THE
MODERNIZATION OF TYPE COMMANDER
HEADQUARTERS AUTOMATED INFORMATION SYSTEM
(THAIS)

by

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An Evaluation of COMNAVSURFPAC's Information Engineering Initiative for the Modernization of Type Commander Headquarters Automated Information System (THAIS)

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ABSTRACT

A state-of-the-art management information system which would allow a Type Command to efficiently control assigned assets by thorough integration of the many currently distinct management systems is critical in this era of rapid technological growth, data overabundance, and expanding naval commitments. A significant problem with the current development of such a system is its inherent large size and a requirement to use an unproven methodology, Information Engineering (IE). This thesis analyzes the modernization of the Type Commander Headquarters Automated Information System, THAIS, identifies problems related to the effort and discusses the use of IE on a major redesign project.

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I. INTRODUCTION

The U.S. Navy requires large database systems to manage its many activities. The design of such database systems has proven to be inadequate for long term system usage and maintenance. Instead of relatively simple revisions to a well established system, whole new systems are designed to accomodate new requirements. This situation is inefficient and wasteful of hard to acquire public funds.

The complicated development of these expansive systems requires an ever increasing effort in project management and design. Consequently, software development methodologies such as Fourth Generation Techniques and Prototyping and Strategic Information Systems Planning methodologies such as Information Engineering (IE) are in use to optimize planning and design efforts in terms of time, monetary expenditures, and end user satisfaction [Ref. 1:p. 1]. However, the effectiveness of each methodology is questionable since they are relatively new techniques and have not been used extensively on large software projects such as the THAIS modernization.

The U.S. Navy has defined a requirement for a large database system which will allow for the efficient management of very extensive data on a large number of units. The system, the Type Commander's Automated Information System or THAIS, in use since 1986, has been undergoing constant

revision. The next revision will be much more extensive and incorporate several smaller database systems which are currently independent, separately-managed systems. Rapid technology change and rapid software applications development, along with increasing amounts of organizational data, has driven the requirement for the utilization of a comprehensive methodology. This methodology must be capable of accurate, efficient and timely project completion which meets with end user satisfaction.

Information Engineering (IE) is an appropriate methodology and was chosen for the Navy project, modernization of THAIS. It is conducive to effective data modeling and supports a variety of database software programs. This methodology provides for strategic planning, design, and implementation of an organization's information system in an efficient, accurate manner. [Ref. 2:p. 221] U.S. Navy interest in IE stems from its focus on data and the derivation of information from the data. The relationship of IE to the structured discipline of engineering, its leading edge of technology status, and the Navy's long tradition of being at the forefront of technological development may also be contributing factors to the Navy's captivation with IE and Computer Aided Software Engineering (CASE) technology.

Utilization of new development methods is not without risks. Untested methods can result in lower quality software. Many times product quality assurance and testing is accom-

plished by letting the end user discover product shortfalls. Untried or untested cutting edge techniques become burdensome to the end user rather than beneficial.

Software quality is a very elusive term. End users expect software, especially expensive software, to be error free and fully documented. Developers, often constrained by budgets, are interested in achieving quality but only to the point where it is cost effective. Oftentimes a software product is incomplete because of this situation which leaves a dissatisfied user with a non-quality product. A formal definition of software quality is:

> Conformance to explicitly stated functional and performance requirements, explicitly documented development standards, and implicit characteristics that are expected of all professionally developed software. [Ref. 3:p. 433]

The Department of the Navy (DON) requires many large, unique software programs to operate ADP facilities, control weapon systems and to manage operational readiness. The management of these large software projects is very cumbersome and oftentimes inefficient. [Ref. 4:p. 65] Through the use of management controls such as program reviews, status reports on cost and schedule adherence, and contractually imposed standards, the DON attempts to monitor "...cost overruns, milestone slips, omitted requirements, incomplete requirements, and inadequate deliverables." [Ref. 4:p. 65] The first two items can be controlled by proper project management. The last three items can be remedied by substantial user input

during software planning and development and by the establishment of a stable information systems architecture.

A stable architecture must be built around organizational data but this is not easily accomplished. Inadequate, out-of-date data may be difficult to format meaningfully. Data integrity is difficult to ensure since project data is often proprietary and the contractor performs the project analysis. Unwillingness to share proprietary data makes data sharing a barrier between the DON and private contractors. Cooperation is needed to ensure successful project completion. Project management may choose cost and schedule adherence over productivity and efficiency during data analysis leading to a lack of program quality. End products may fall short of the end user's expectations and may even be unusable due to a lack of end user input during the design process. The time lag between discovery of problems or the request for additional requirements and the actual implementation of the corrective changes or new requirements is often too great to be effective. The above problems lead to poor product quality and excessive time to project completion. [Ref. 4:p. 66]

The introduction of IE sought to solve problems associated with traditional design such as (1) overemphasis of applications on functions/processes and underemphasis on data which leads to a lack of understanding of long term information needs, (2) lack of productivity and standardization from underutilization of CASE tools, and (3) lack of user invlove-

ment in the design process. Utilization of IE assures an organization, through development of a stable informations system architecture, of the delivery of a higher quality product.

The DON's interest with IE thus exhibits a desire to produce high quality products which are user friendly and user supported. However, due to modification of the IE Methodology in the THAIS modernization project, rapid prototyping was introduced to complete the first module. Through an analysis of the DON's modernization of THAIS, this thesis will determine the effectiveness of Information Engineering on a large database design project. The issues of quality control, project management, end user involvement and end user support will be addressed.

The thesis will address the following questions:

1. What are the benefits which Information Engineering adds to the software development process and are these benefits worth the time, effort, and funding required to develop the software?

2. What are the advantages and disadvantages of exporting the methodology used for THAIS modernization to other type commands?

3. How is quality control improved with Information Engineering?

4. Why did process modeling fail in the THAIS modernization project?

5. Can Information Engineering be altered in order to be effective on large scale projects?

6. Is Information Engineering an effective methodology for the design and implementation of a large database project based on the results of the THAIS modernization?

Chapter II provides the background information of the THAIS modernization project and also on Information Engineering and the decision for its utilization on the THAIS project.

Chapter III discusses the detailed data modeling processes specific to Information Engineering and the THAIS modernization project.

Chapter IV discusses the aspects of quality assurance required in a successful software design project. In addition it discusses how Information Engineering ensures quality in its methodology.

Chapter V discusses CNSP's dissatisfaction with Information Engineering on the THAIS modernization project and the resultant corrective action taken by the DON to successfully complete the intitial module of the project.

Chapter VI provides conclusions and recommendations for the DON to use for future projects where Information Engineering is utilized.

II. BACKGROUND

A. PROJECT BACKGROUND

Any large organization has vast amounts of data which it uses for day-to-day operations as well as in support of its strategic plans. Many organizations cannot foresee the future nor envision their information needs. Without foresight, it becomes exceedingly difficult to develop an information system capable of directing an organization toward its strategic goals. Large investments required for information systems development, insufficient understanding of organizational data and processes, and lack of long term focus make it difficult for management to be committed to project development. Ad hoc response to emerging information needs becomes commonplace which can be overly expensive in the long run. [Ref. 5:p. 6]

The U.S. Navy has defined strategic goals and objectives but does not possess a sound infrastructure for development of its information resources. An ad hoc response tendency has been widespread but commitment to the development of a sound information systems infrastructure has reversed the trend. This infrastructure will provide several enabling capabilities:

- Mechanisms to share data resources.
- A communications network that permits widespread interconnectivity.
- A productive process for developing application software.

- High quality technical support services (technology assessment, technical support of users and products, training services, etc.). [Ref. 5:p. 5]

Another problem associated with the extensive organizational data is the difficulty in accumulating and compiling information from the assorted data. An answer to this data manageability problem is in the utilization of an automated information system.

> The military is highly dependent on automated information systems (AIS) for the reliable operation and maintenance of its weapon systems and other critical military operations such as the management of spare parts as well as day-to-day administrative and financial transactions involving personnel payroll, and contract management. These functions are vital for the efficient operation of the United States defense establishment. The Department of Defense (DOD) currently spends about $9 billion each year on general purpose automated data processing equipment, software, and related services. This "information technology budget" represents a commitment by DOD to tens of billions of dollars in future expenditures for the development and acquisition of new automated information systems. [Ref. 6:p. 1]

The U.S. Navy realized in 1976 that a system was needed at the Type Commander level. As a result, Type Command Headquarters Automated Information System, THAIS, was initiated.

1. What is THAIS ?

THAIS was conceived in 1976 as a special project at the direction of the Chief of Naval Operations OP-091. A study titled "ADP Software Support for Type Commander Headquarters - Requirements Study - Phase I" was completed but consequently shelved until 1978 when the Commander in Chief, Atlantic Fleet became interested. The economic analysis required for development approval was completed in November 1979 and the

initial Functional Description (FD) appeared in December 1980. Development began in 1981 by NARDAC Norfolk, whose Commanding Officer also acted as Deputy Project Manager with the Primary Project Manager being Commander, Naval Data Automation Command. [Ref. 7:pp. 1-2]

THAIS was envisioned as a system to ease the burden of information management at the Type Commander level. The stated THAIS missions are:

- Provide on-line, interactive management information system to 7 TYCOMS.
- Build backbone databases in 10 functional areas.
- Improve data reliability.
- Accelerate management report preparation time.
- Expand data utility.
- Provide earlier problem recognition.
- Make more efficient use of available resources. [Ref. 8:p. 15]

The system originally involved a prototype which ran on a UNIVAC System 80 but was converted to run on Honeywell DPS-6 machines in 1983. After successful implementation on the DPS-6 machines, the system was designated initially operational capable and became utilized by Commander Naval Surface Forces Atlantic (CNSL). The system continued to gain interest and additional requirements were rapidly requested, ultimately calling for a new revision of the software to be produced. [Ref. 7:pp. 1-3]

The first revision, THAIS Phase II, was initiated in 1984 and completed in 1986. [Ref. 7:p. 3] Revisions occurred rapidly since that time with revision two in 1987/88, revision three in 1988, and revisions four and five in 1989. The

current version, 5.1, was installed in June 1990. However, modernization efforts continue. [Ref. 8:p. 13]

2. Why Update THAIS ?

Growth of the U.S. Navy since the origination of THAIS and rapid and extensive increases in information requirements have combined to necessitate a larger system capacity and more extensive capabilities. Figure 1 demonstrates the current utilization of THAIS throughout various Type Commands. THAIS usage started with CNSL in 1984 and spread to all six Type Commands, Commander-in-Chief Pacific, and Commander, Second Fleet by 1990. As depicted in Figure 1, each commander does not utilize each module. As the system expands and the database is refined, module usage will increase. Widespread THAIS usage at the Type Commander level is important because each Type Commander utilizes similar data and has similar information requirements and flows in its daily operations. All Type Commanders are challenged with the problem of managing a very large and dynamic yet essential database. The database also possesses the problem of various security classifications within a single database but many users with varying levels of security clearances require access. Increased information sharing between Type Commanders could significantly reduce similar problems within various commands.

Concurrently with the U.S. Navy's increased demand for information, computer technology developed rapidly. The ADA programming language was introduced to high level DON person-

THAIS MODULE/SUBMODULE USAGE
as of July 1990

Module/Submodule	SURF LANT	SUB LANT	AIR LANT	SURF PAC	SUB PAC	AIR PAC	CINC PAC	2ND FLT
ADHOC	■	■	■	■	■	■	■	■
Support Software	■	■	■	■	■	■	■	■
Message Processing (PCMT)	■	■	▒	▒	■	■	▒	
Command Index	■	■	■	■	■	■	■	■
Employment	■	■	■	■	■	■		■
Executive Summary	■	■	▒	■	■		■	
SORTS	■	▒		▒	▒		■	
Inspection: Setup	■	▒	■	■	▒		■	
Inspection: Tracking	■	▒	■	■	▒		■	
Logistics: CASREP	■	■		■	■		■	
Logistics: DLR	■	■		■	■	■	■	
Finance: TAD	■	■			■			
Personnel		■			■			
Readiness: Training	■		▒	■				
Admin: Cor & Dir		■		■				
Admin: Staff		■		■				
Aviation Maint: AIRS			■			■		
Aviation Maint: AS			■			■		
Aviation Maint: AMRR			▒			▒	▒	
Aviation Maint: SDLM						■		
Aviation Maint: SPINTAC						■		

■ = using, ▒ = Planning to use, blank = not using

Figure 1 THAIS Utilization by Type Command [Ref. 7:p. 14]

nel who sought to utilize the language for many new projects. Several software development methodologies evolved during this period of information technology growth which the U.S. Navy could apply to solve its increased information system requirements and utilize the ADA language.

B. INFORMATION ENGINEERING BACKGROUND

There are alternative software development methodologies which are variations on the classical Software Development Methodology or the "waterfall" method. Prototyping, Fourth Generation Techniques and SAGE-SDM are examples of variations and improvements on the classical methodology. Each has its positive and negative characteristics. Figures 2-5 depict these methodologies.

Prototyping is an iterative process of quickly designing and building system models. The positive characteristics are: hastening of overall system development time and high degree of end user involvement during the design. On the negative side, the end user is more aware of the development status and may often like what appears to be a complete, working model of the system and therefore expects to use the system as is but is quite disappointed when informed of the prototype's inherently incomplete nature. The end user often demands to use the incomplete version without regard for the software quality or system maintainability. Also, sacrifices in design

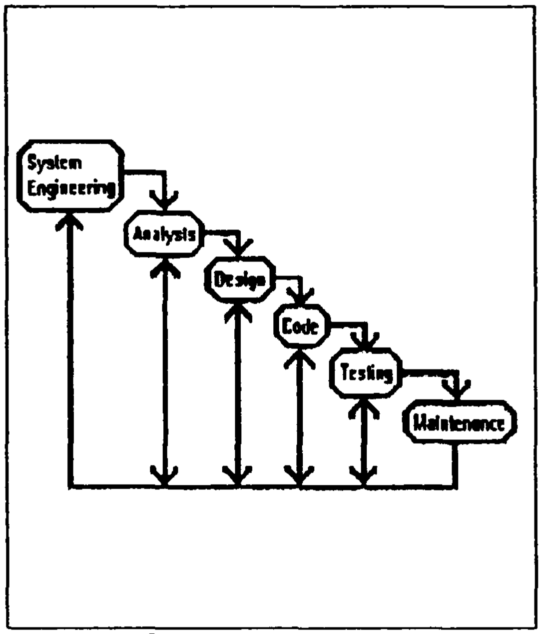

Figure 2
The Classical Method
[Ref. 1:p. 2]

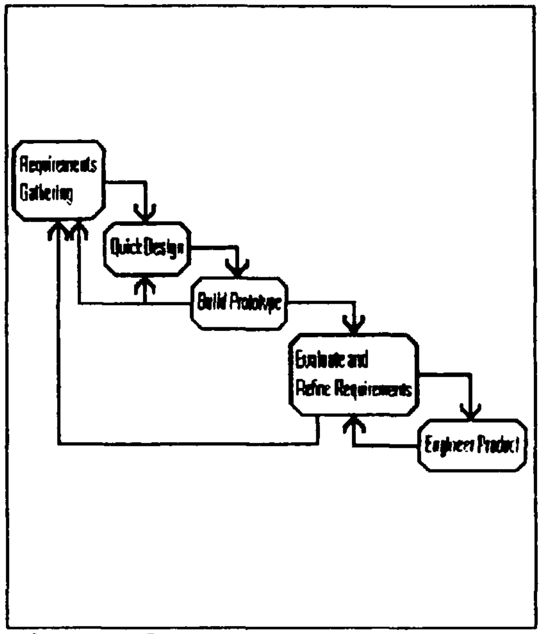

Figure 3
The Prototyping Method
[Ref. 1:p. 4]

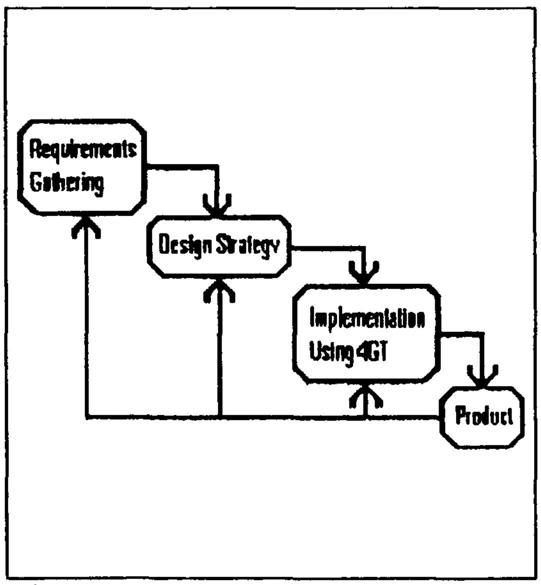

Figure 4 The 4GT Method
[Ref. 1:p. 5]

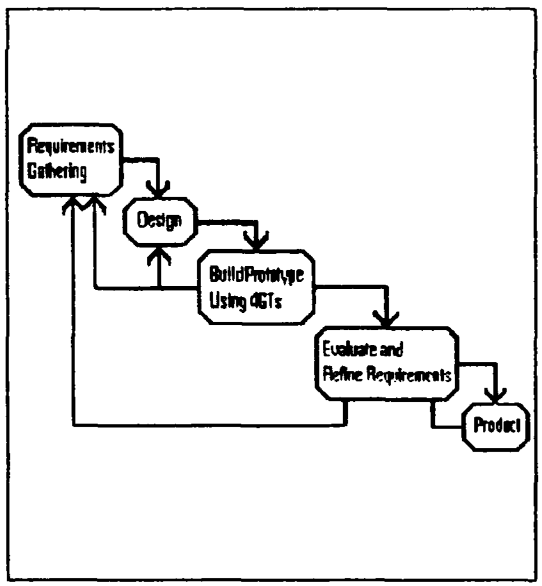

Figure 5 The SAGE Method
[Ref. 1:p. 7]

are made to speed development which may remain with the system after the prototype is accepted. The developer may neglect or may not have the funding to correct the design to the original specifications. [Ref. 1:p. 5]

Fourth Generation Techniques is a methodology which includes several software tools "...which enable the software developer to specify some characteristic of software at a high level." [Ref. 1:p. 5] These characteristics are screen design, code generation, report generation, graphics, and several others. As a positive aspect, for small or medium applications this methodology decreases time required for the analysis and design phases. Larger projects require more time and often do not realize any significant time savings over the classical design methodology. [Ref. 1:p. 6]

SAGE-SDM, was developed by the Department of Energy's Idaho National Engineering Laboratory (INEL) and is an amalgamation of the Classical Methodology, Prototyping, and Fourth Generation Techniques. This methodology involves the user extensively which imparts a sense of ownership, reduces development time significantly, and is conducive to the design situation where the user requirements are hard to define. One major drawback to this methodology is the compromises made during implementation to satisfy time constraints in order to deliver a system which is usable per the customer's request. Although the developer would like it to be perfected before turning it

over to the user, he is often forced into delivering an incomplete product. [Ref. 1:pp. 7-8]

The above Software Development Methodologies (SDM) are intended for use in conjunction with a Strategic Information Systems Planning Methodology (SISP). IE was chosen as the SISP for the THAIS modernization project and SAGE-SDM was chosen as the SDM. The need to utilize both methodologies arises from the requirement to develop a stable information systems architecture and follow up with an efficient software application development.

1. What is Information Engineering ?

There are several definitions of Information Engineering which may differ somewhat but each is centered on modeling organizational data and each emphasizes the creation of a stable information systems architecture. One interpretation is that of James Martin, one of the major contributors to the IE Methodology, who states that IE is:

> ...a process by which information systems are developed that precisely support the objectives of the business enterprise. The IEM's$_{TM}$ logical, common sense progression of steps is rigid enough to ensure comprehensiveness and accuracy, yet flexible enough to model precisely the uniqueness and idiosyncrasies of the business.
>
> The IEM's$_{TM}$ focus on the information needs of the entire enterprise, rather than compartmentalized data processing functions, is an essential point of differentiation from other philosophies. [Ref. 9:p. 2]

Clive Finkelstein, another major contributor to the development of IE, describes IE as a strategic development approach which "...is an integrated set of techniques which lead from strategic planning to the implementation of informa-

tion systems which directly support those plans (of the business)." [Ref. 10:p. 2.2]

Richard Hackathorn and Jahangir Karimi further explain the primary focus of IE as being directed:

> ...specifically at translating a corporate focus (a strategic plan, expressed as organizational mission statement) into an information systems architecture (ISA), which can be directly translated into data, application, and geographic architectures. [Ref. 11:p. 203]

These descriptions emphasize the importance of a strategic perspective throughout the development process. Although it is not stated, a data-centered approach is assumed in these definitions. This is a major differentiation from and improvement upon the previously discussed SDM's. Centering the development around data which has been well-defined by key personnel within the organization allows for easier adaptation to new requirements over the lifetime of the system. [Ref. 12:p. 129] During development, data is isolated and modeled based on its importance to the organization and not on the current use of the data. Data is central to this methodology but processes, technology and management issues are also keys to a successful implementation. [Ref. 13:p. 246] Figure 6 depicts the IE methodology.

There are several versions of IE, none of which has stood out as a preeminent, all-encompassing method [Ref. 11:p. 205]. Clive Finklestein is the founder of the Information Engineering Systems Corporation (IESC), which is the

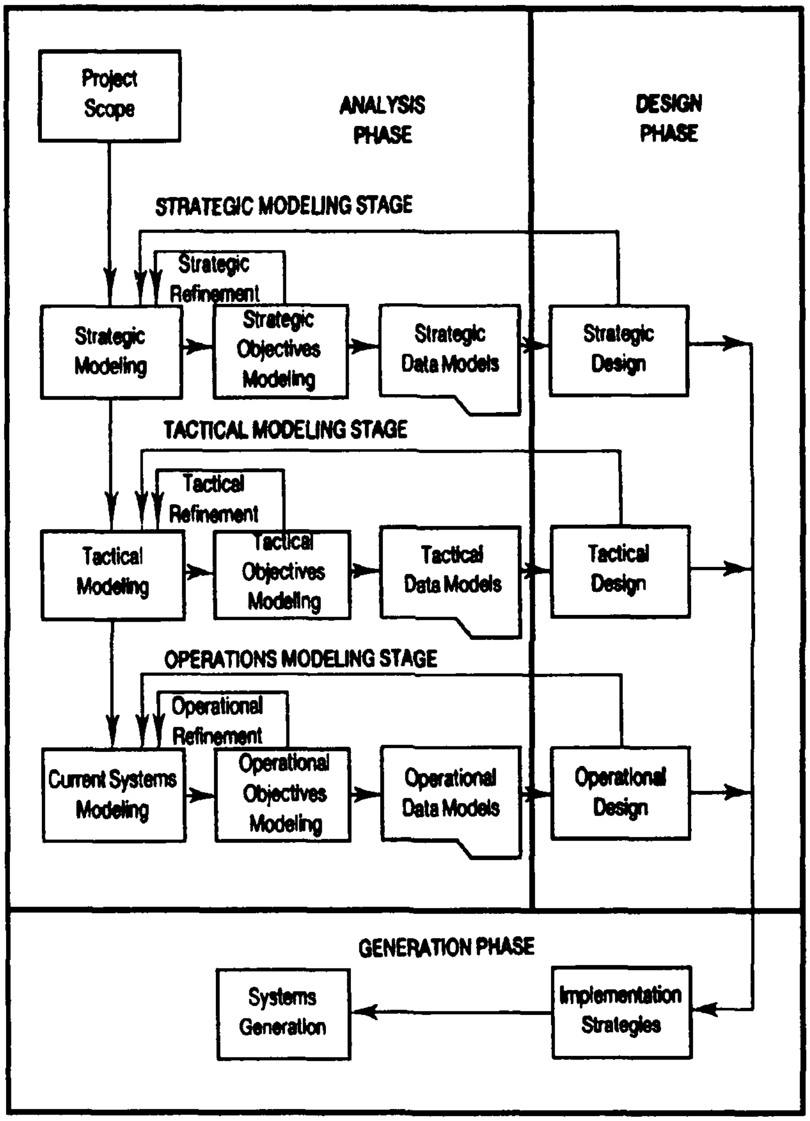

Figure 6 The IE Methodology [Ref. 2:p. 222]

contractor for the IE portion of the THAIS modernization, so his interpretation of IE will be described.

This IE method is comprised of three broad phases which are subdivided into stages as follows:

- Analysis Phase [Ref. 2:pp. 223,241]
  - Project Scope Stage
    - Identify Project Area
    - Select Project Software
    - Establish Project Plan
    - Establish Project Teams
    - Set Project Budget and Funding
    - Schedule IE Workshops
  - Strategic Modeling Stage
    - Strategic Modeling
    - Strategic Objectives Modeling
    - Strategic Refinement
  - Tactical Modeling Stage
    - Tactical Modeling
    - Tactical Objectives Modeling
    - Tactical Refinement
  - Operational Modeling Stage
    - Current Systems Modeling
- Design Phase [Ref. 2:p. 229]
  - An automated phase that uses a design dictionary. It comprises Strategic, Tactical and Operational Design.
- Generation Phase [Ref. 2:p. 231]
  - This phase defines implementation strategies appropriate to each part of the integrated s , ategic and tactical data models.

A knowledge base is a primary aspect of IE which differentiates it from other methodologies. This knowledge base is a collection of data models, data flow diagrams, process specifications and any other pertinent planning and analysis phase products. Design phase products such as screen and report designs are also stored as they are created. The knowledge base is important because it serves as an active

repository which CASE tools can utilize. It can be accessed to automatically create planning or design products which improves development time and provides for easier maintenance and revisions. [Ref. 13:p. 247]

2. **Why Utilize Information Engineering ?**

IE is an adaptive, contemporary methodology which can help an organization define its data resources and develop a complete information system which is compatible with the organization's strategic goals. It employs CASE technology which allows it to draw from a knowledge base to integrate and automate planning, analysis, design and code generation functions. IE structures information to enable managers to readily obtain key information without time consuming data processing. Fourth Generation Languages aid in timely project completion and cost cutting through code reusability and code library generation for future revisions or for other projects. The specific advantages of IE are:

- It is based on a precise model of the business enterprise, and therefore can effectively support its objectives.
- Intensive user involvement, with the help of diagrammatic techniques, ensures the systems' completeness and accuracy.
- Its emphasis on data as well as applications provides a stable, long-term foundation for processes and business rules that change as the business changes.
- CASE tools add speed and enhance accuracy, and make possible development by users as new needs and requirements arise.
- It is accompanied by comprehensive briefings and guidelines for managing the role changes for managers, users, analysts and programmers.
- It includes participation in an extensive research and development program that continues to refine and enhance the methods it embodies.

- It achieves data consolidation: IE draws includes cross-checking steps both manual and automated, to identify redundant versions of data.
- It is highly automated: Both strategic and tactical plans and data are captured by expert systems in an expert design dictionary. [Ref. 9:p. 10] and [Ref. 2:p. 234]

The U.S. Navy chose IE over other methodologies because of the above considerations and because it fits well with the Navy's commitment to planning for the future. With reduced appropriations and constant if not increasing commitments, increasing organizational data, expanding technology and extended data sharing, the U.S. Navy demanded a methodology capable of satisfying these needs.

THAIS is an important system because it links the vast data concerning individual naval units with the strategic goals of the U.S. Navy through the high level management of the Type Commanders. Information Engineering is an excellent method for matching strategic planning with a sound information systems architecture through strategic, tactical and operational modeling of organizational data and the associated processes. For these reasons, Information Engineering is the chosen methodology for use on the THAIS modernization project. The specific aspects of a key portion of IE, data modeling, is discussed in the following chapter.

III. MODELING THE DATA

Today's organizations are saturated with data. The management of information gleaned from these data is a key issue during strategic organizational planning. Oftentimes, senior management of large organizations is unfamiliar with an information-rich realm in which to plan since they were educated and oriented to their business when information was relatively scarce and information management was virtually nonexistent. These same senior executives are expected to create an effective strategic plan with a wealth of information, some of which they cannot envision. [Ref. 5:p. 4] The intrinsic value of the information provided from accumulated data cannot be ignored as it may provide answers to as yet unknown questions which could directly affect the future of an organization. Data modeling significantly aids an organization in its data refinement and creation of information essential to organizational management.

A primary problem associated with utilizing information for strategic planning is in developing a management information system which contains accurate data and provides the appropriate information to the proper personnel. The process of analyzing data and fitting it into an information system is

known as data modeling and is a central part of IE.

> Data modeling offers an analysis and design method. It helps to define the requirements of users, and then to design systems that satisfy those needs. Data modeling leads to development of logical data base designs based on user's needs. [Ref. 2:p. 59]

Data modeling consists of three stages: strategic, tactical, and operational. The data refinement process throughout these stages produces a data model which consists of an entity list and a data map. The data model represents fundamental organizational data, data attributes, and data relationships. It is also the primary product of IE and the primary input to the software development process. [Ref. 2:pp. 33-37]

Data identification and verification is not the only function of this stage of development. The strategic model provides a broad perspective of the organization's goals. The tactical model must define statements which support the strategic goals but are specific enough to generate management rules. IE, which utilizes expert systems (IESC utilizes *USER: Expert Systems*) to automate the design process, will use the management rules as part of the expert system's knowledge base. The process of devising the rules is known as tactical objectives modeling.

> Tactical objectives apply to the operational end of the organization. As for strategic objectives, tactical objectives are also called performance indicators. They must be measurable and decompose into work, requiring effort to achieve. [Ref. 2:p. 202]

Each modeling stage provides a distinct level of data refinement which will be described in the following sections.

A. STRATEGIC DATA MODELING

The Strategic Modeling stage of an IE project focuses on identifying the critical success factors which enable an organization to attain its strategic objectives. Strategic goals, often vague or misunderstood by many executives, must be delineated and verified in order to ascertain proper critical success factors. Once this is accomplished, the strategic model can be outlined. The project flow through each modeling stage within IE and the relationship to implementation is depicted in Figure 7. The specific steps of data modeling are depicted in Figure 8.

> A strategic model comprises high-level strategic entities of interest to senior management of a project area. These strategic entities are so called because they contain primary and foreign key attributes to establish associations between related entities. [Ref. 2:p. 203]

The strategic model represents an organization in terms of its data, not in terms of the processes which utilize the data [Ref. 14:p. 2.8]. This is an important point because the processes may change but the data is stable. "Although the information requirements of executives change from month to month, the basic data that represents an enterprise does not change much unless the enterprise is itself drastically changed." [Ref. 15:p. 23]

The goal of this stage is to create a stable strategic model which will spawn stable tactical and operational models which will lead to the creation of a dynamic yet sound management information system.

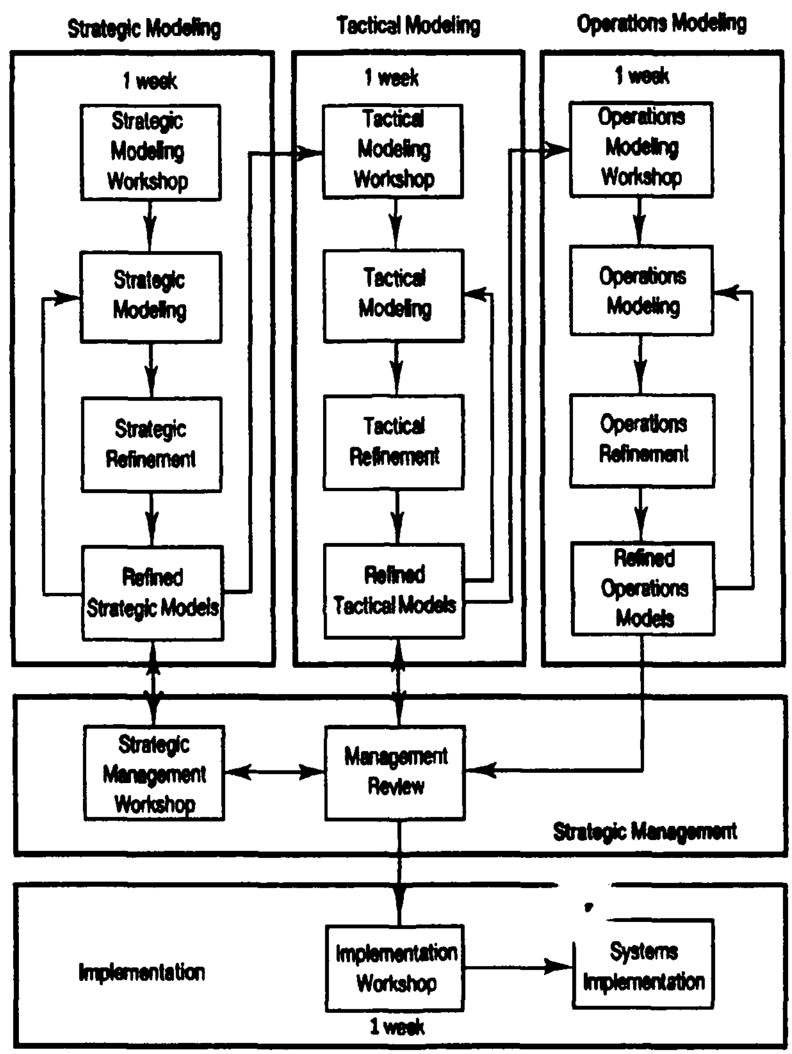

Figure 7 Data Modeling Flow within IE [Ref 2:p.244]

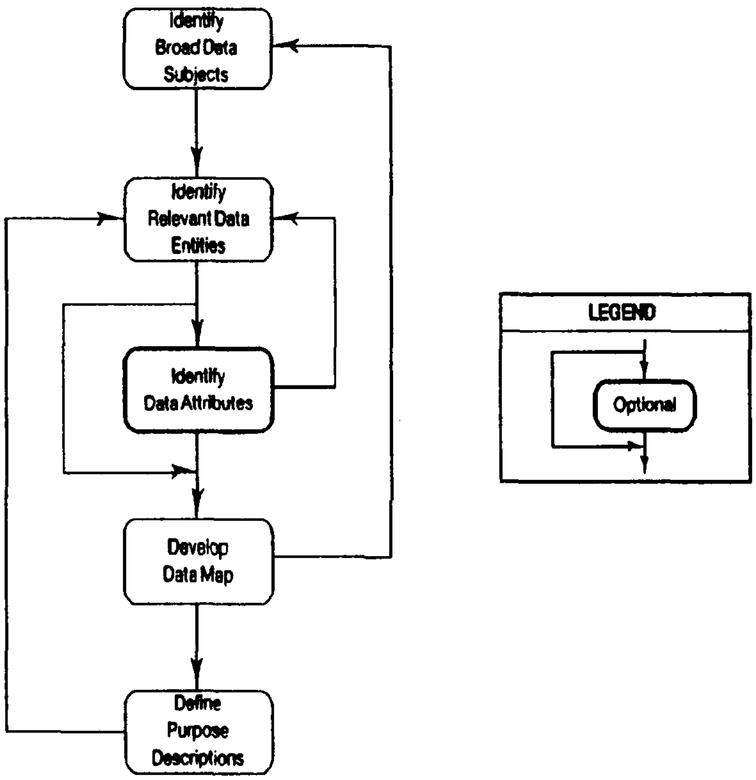

Figure 8 Data Modeling Steps [Ref. 2:p. 272]

The Information Engineering Systems Corporation (IESC) has an effective procedure for conducting strategic modeling. This organization holds a workshop with executives to verify strategic goals, determine organizational policies, identify key personnel, establish milestones and determine performance monitoring procedures. [Ref. 14:p. 2.15]

As a contractor for the THAIS redesign project, IESC conducted a Strategic Modeling workshop in January 1990 with the Commander Naval Surface Forces Pacific (CNSP) staff, which served as the prototype site for the THAIS modernization, and other associated project personnel. The result was a division of data into seven functional areas:

- Logistic Equipment (including Casualty Reports or CASREPS)
- Logistic Supply
- Shore Based Facilities
- Readiness
- Employment
- Financial Management
- Performance Monitoring [Ref. 16:p. 1]

The current THAIS version has eleven separate subsystems and databases with much redundant data. The proposed revision will consolidate the data into one database and resolve the data redundancy issue. An example of data redundancy within CNSP is the requirement for CASREP data in the Logistic Equipment area and in the Readiness area. Since both areas require the same data, one database should suffice and would be more appropriate since data currency and consistency would be more easily maintained. However, currently two distinct databases are utilized.

A strategic objective of the redesign effort was to give development priority to those functional areas most affected by a shutdown of the Honeywell DPS-6 computers [Ref. 16:p. 1]. The operating expenses of the Honeywell computers will be transfered to each Type Command from Naval Computer and Telecommunication Command (NCTC) at the end of FY91 which is a factor driving the completion of the redesign by the end of FY91.

As part of the THAIS modernization, a PC based system would replace the Honeywell minicomputers. The PC based system is must less expensive to maintain and is believed to be more flexible in terms of ease of use and information transfer between type commanders and subcommands. [Ref. 18:p. 2] For example, with the present configuration, status reports are mailed to subcommands who manually annotate corrections and mail them back to the type commander who then enters the corrections into the database. With a PC based system, reports can be corrected on a local database, the corrections stored on floppy discs and then mailed to the Type Commander for automatic entry into the master database.

Several functional areas were identified to be critical in the event of a Honeywell computer shutdown. These areas were Logistic Equipment (CASREP), Readiness and Employment. [Ref. 16:p. 1] The CASREP area became the first modeled area. Tactical modeling, the next stage after strategic modeling, started with the CASREP module on 05 March 1990 [Ref. 16:p. 1].

There are three rules which link the strategic plan to organizational data.

- Rule 1: Policies and issues relate directly to entities.
- Rule 2: Goals and objectives relate directly to attributes.
- Rule 3: Strategies and tactics relate directly to associations. [Ref. 17:p. 19.15]

An example of a report generated as a result of strategic modeling is the Policy Report, Figure 9. This report is the result of the need to relate organizational policies to data entities or to create a policy when a group of entities lack an associated policy. [Ref. 17:p. 19.15] Other outputs of strategic modeling are:

- Entity Report
- Attribute Report
- Association Report
- Extended Purpose Report
- Graphical Data Map

B. TACTICAL DATA MODELING

The tactical modeling stage of IE is concerned with refining strategic objectives to a level consistent with a specific functional area. Managers who participated in strategic modelng direct the mid-level managers in the definition of strategic objectives to obtained from a specific functional area at the tactical level. [Ref. 2:p. 196]

> A tactical model comprises lower-level tactical entities of interest mainly to middle management of a project area. These tactical entities contain non-key attributes (called tactical attributes) which provide detailed data of interest to these middle managers. [Ref. 2:p. 203]

Policy Report : Active
Functional Area : **READINESS REPORTING**

Page : 1 Date : 22-Jul-1990

ADVANCED TRAINING POLICY

ASSURE UNITS ARE READY FOR ADVANCED TRAINING WHEN CHOPPED TO C3F.

---------------- linked to the following entities (cancelled links in parentheses) ----------------

LOGISTICS-EQUIPMENT

H/W.

PERSONNEL

(PERSON), UNPLANNED LOSS ASSIGNMENT.

READINESS REPORTING

ORGANIZATION TRAINING PLAN, PERSON TRAINING REQUIREMENT.

BILLET QUALIFICATIONS

Shipboard billet qualifications will be identified and maintained.

---------------- linked to the following entities (cancelled links in parentheses) ----------------

PERSONNEL

BILLET.

READINESS REPORTING

BILLET TRAINING REQUIREMENT.

DEPLOYMENT READINESS

COMNAVSURFPAC will endeavor to have all assets ready to deploy M1 in all primary mission areas.

---------------- linked to the following entities (cancelled links in parentheses) ----------------

LOGISTICS-EQUIPMENT

H/W.

Figure 9 THAIS Policy Report

The strategic data model is expanded into functional areas, seven in the case of CNSP, at the tactical level as represented by Figure 10. An organizational policy determined during

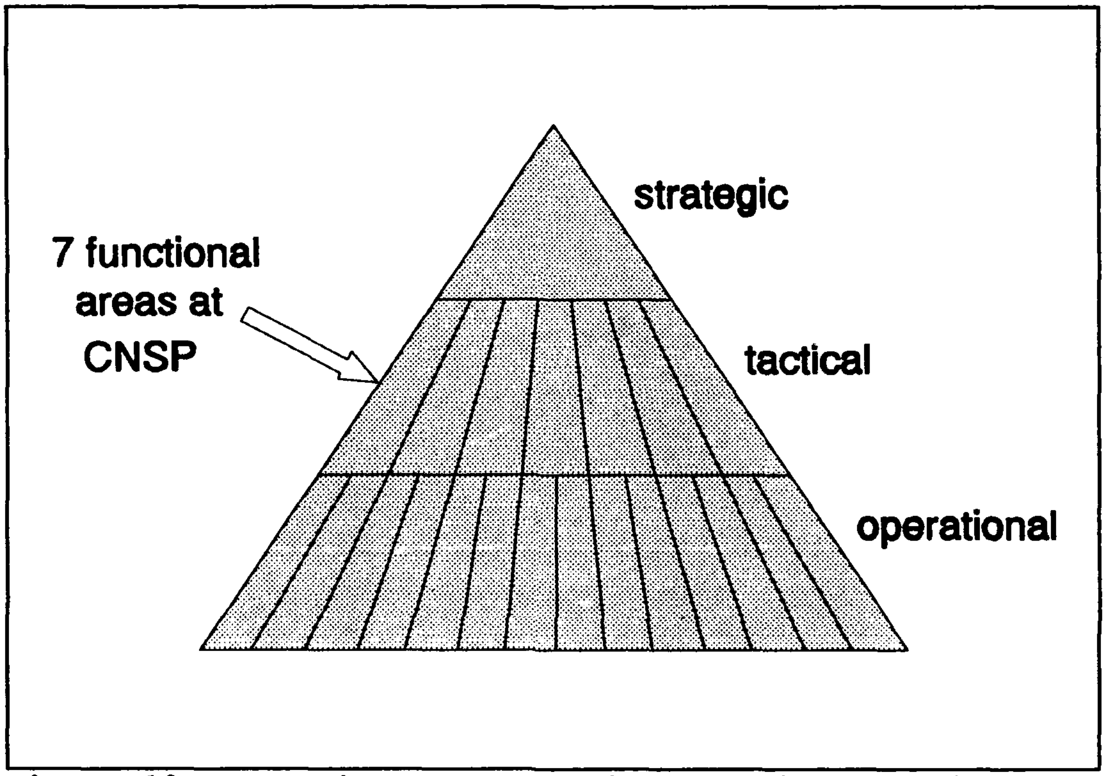

Figure 10 Expansion of Strategic Model into Tactical and Operational Models [Ref. 2:p. 246]

strategic modeling such as "Mobile u ,ts are required to undertake a certain set of training, exercises, and inspections," is used to identify data entities which are then further refined during tactical modeling. One entity associated with the above policy is the Employment Scheduling module entity "organization." Middle and operational managers are queried on the aspects of their functions such as the utilization of CASREP data in each organization or the relationship

of organization data to the Readiness area. Data related to these functions are defined and analyzed. Unneeded or redundant data is discarded. [Ref. 14:p. 2.16] The model is streamlined but all pertinent data according to the "experts" or operational managers is captured. For example, the entity mentioned above, "organization," is subsequently refined or normalized into nine entities. These entities are:

- organization
- organization location
- organization location reason
- organization location reporting category
- organization role
- organization structure
- organization structure category
- organization structure reason
- organization type
- organization requirement
- organization resource readiness
- organization TRADA history
- organization training plan

Involvement by management throughout the data refinement is critical since it creates a feeling of ownership and responsibility to make the system work.

A basic premise of data modeling is that some data are related to other data. The relationships are determined through user involvement and are automatically documented in a data dictionary. Physical depictions of data models, called data maps, are then generated for analysis and verification. [Ref. 15:p. 28] Figure 11 is a partial Readiness module data map which shows the relationships of organizations as modeled within the module.

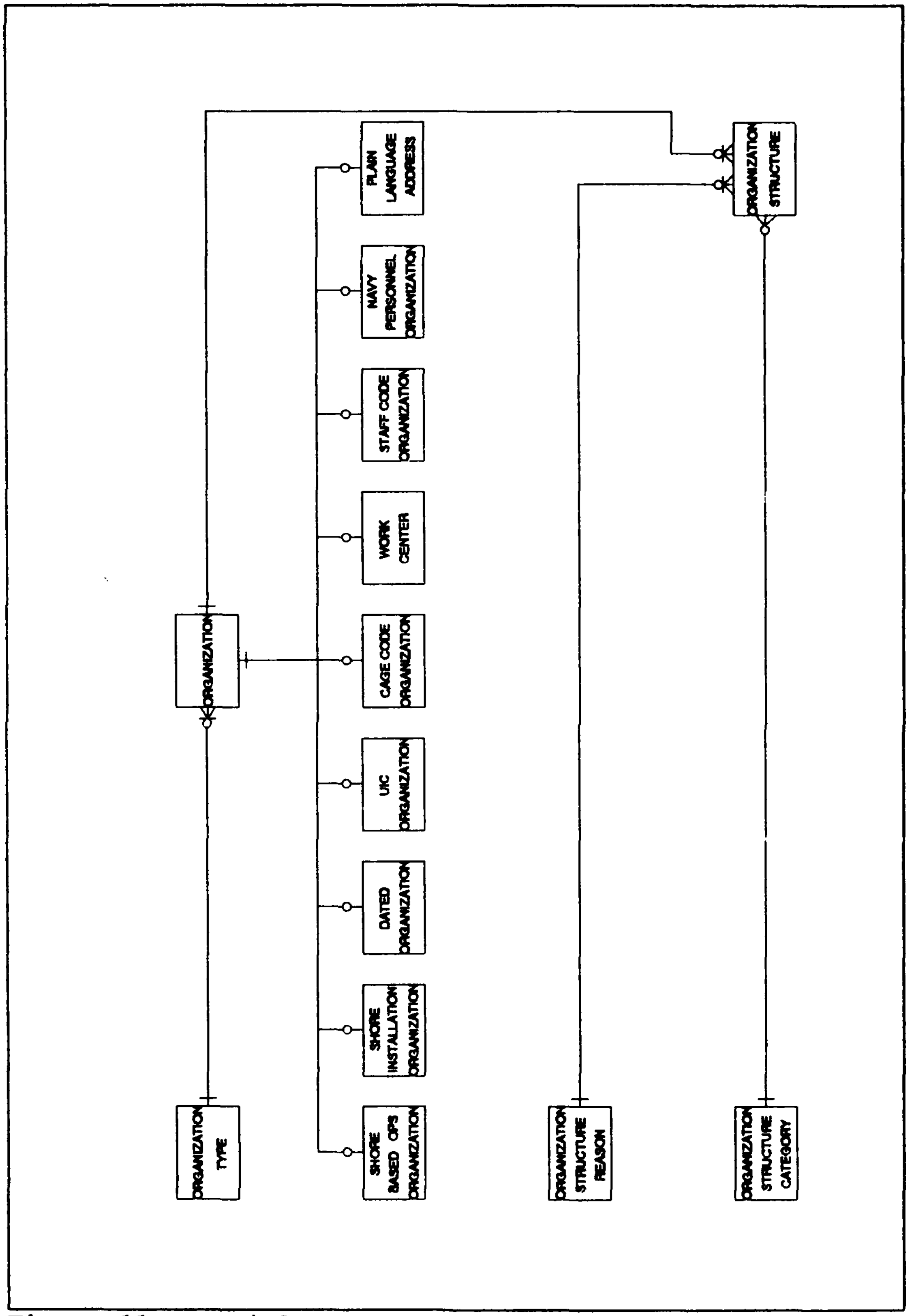

Figure 11 Partial THAIS Datamap

Tactical modeling ensures, through data structuring, that data are defined independently of their utilization in organizational processes [Ref. 15:p. 260]. Data must be modeled in this fashion. Modeling data according to its use will result in a poor system architecture in that if the processes change, as is often the case, the architectural stability will be jeopardized. The result is large reinvestment in time and money to design a new system based on the new processes. Tactical modeling seeks to eliminate this problem by ensuring that data are isolated and modeled without regard to any process thereby securing a stable architecture. [Ref. 15:p. 5] Figure 12 represents a tactical modeling output, the Entity Purpose Report. This report lists each entity in the functional area and its purpose for existing in the database. Other outputs of this stage are the same as strategic modeling, with the exception of the Policy Report, but are limited to a specific functional area instead of the whole organization.

Upon completion of tactical refinement the tactical model is further refined in the third and final data modeling iteration, the Operations Data Modeling stage.

C. OPERATIONS DATA MODELING

This stage is a formal cross-check of strategic and tactical data modeling. It uses organizational documents to verify that the modeled data is complete and appropriate.

TYPE COMMANDER READINESS REPORTING
Entity Purpose Report : Active
Functional Area : READINESS REPORTING

Page : 2 Date : 19-Jul-1990

Entity : CASREP 1PARTS AMPLIFICATION
Purpose : CASUALTY REPORT 1PARTS AMPLIFICATION

Captures amplifying remarks relative to the 1parts section of a CASREP requisition.

Entity : CASREP FACTORS CONTROLING ETR
Purpose : CASREP FACTORS CONTROLLING ESTIMATED TIME OF REPAIR

Allows recording of factors impacting or justifying the estimated repair date reported on a CASREP.

Entity : CASREP HARDWARE STRUCTURE
Purpose : CASUALTY REPORT HARDWARE STRUCTURE

Identifies a relationship between a CASREP and the hardware associated with a CASREP. This entity is used to indicate the hardware that is down (being CASREPed) as well as any hardware whose effectiveness is impacted by the down hardware.

Entity : CASREP HARDWARE STRUCTURE TYPE
Purpose : CASREP HARDWARE STRUCTURE TYPE

Contains the valid values applied to a piece of hardware associated with a casrep. Indicates whether the hardware is down or impacted by the downed hardware, i.e. chilled water system is downed, the sonar is affected.

Entity : CASREP MESSAGE
Purpose : CASREP MESSAGE

Used to report the status of significant equipment casualties. Comparing this with the MCC for equipment will allow the TYCOM to verify the urgency of the readiness category reported by an organization.

Entity : CASREP PRIORITY
Purpose : CASREP PRIORITY

Used to determine a priority rating (1 thru 9) of a CASREP message based on a c-rating (C2, C3, C4) and a deployment status.

Entity : CASREP READINESS RATING
Purpose : CASREP READINESS RATING

Identifies the level of readiness (which is the level of impact on the ships capability to perform its assigned missions) when a hardware item is reported on a CASREP as being down.

Figure 12 THAIS Entity Purpose Report

This stage does not require upper or middle level management but can be completed by data administrators or, in the case of THAIS, by Type Command staff. [Ref. 2:p. 229]

> An operations model comprises day-to-day operational level entities (called operations entities) containing detailed non-key attributes of interest to staff at the operational level of an organization. [Ref. 2:p. 203]

The inputs to this stage are the same as in the tactical stage: management statements, entities, attributes, associations, and purposes describing the importance of entities. [Ref. 19:p. 2.11] These inputs are massaged by the end users with the help of the IE project personnel into final products. To continue the example from tactical modeling, the entities organization, organization location, and organization type are characterized as alphanumeric with length 50, upper case alphanumeric with length 30, and upper case alphanumeric with length 1, respectively, during the operational modeling stage. Final data refinement is attained through the following:

Attribute characterization:
: Capture the physical characteristics of the attributes, i.e. data storage type, data length, and domain of values.

Populate Static Reference Tables:
: Define values for any new, and populate all static reference tables.

Data Access Authority Validation:
: Re-affirm the data access authority for each entity with respect to each functional user community related to the system.

Data System Storage Size Estimating:
: Estimate the number of records in each entity, the % change, % new, % deleted, average record lifetime.

Data Capture Strategy Plan:
: Identify specific data capture points (organizations or places), authorities, frequencies, and policies for all data to be captured by the new system. [Ref. 19:p. APP 3.8]

One technique for eliminating redundancy, precisely capturing information requirements, and integrating complex data architectures is normalization. [Ref. 19:p. 5.28] Normalization aligns each attribute to an entity and distinguishes entities which may be identical but have different names or independent entities with the same name. It simply provides a clear understanding of each entity and attribute. [Ref. 2:p. 94] Data normalization can be taken to several levels generally no higher than fifth but theoretically, although impractical, to the N^{th} normal form. Some normalization is esential because it provides flexibility in a relational data structure. [Ref. 20:p. 1] The definitions of the first through fifth business normalization steps, as used by IESC on this project, are listed below. An example accompanies each step. An underlined attribute indicates a primary key and double parentheses indicate a repeating group of attributes. [Ref. 2:p. 151]

First Business Normal Form (1BNF):

Identify and remove repeating group attributes to another entity. The primary key of this other entity is made up of a compound key,..., or instead another unique key based on the business needs.

1BNF entities for PRODUCT:

PRODUCT (<u>product number#</u>, product name, cost price, selling price, warehouse number#, warehouse address, quantity on hand)

PRODUCT SUPPLIER (<u>product number#</u>, <u>supplier number#</u>, supplier name, supplier address)

Second Business Normal Form (2BNF):

Identify and remove those attributes into another entity which are only partially dependent on the primary key and also dependent on one or more other key attributes, or which are dependent on only part of the compound key and possibly one or more other key attributes.

2BNF entities for PRODUCT:

PRODUCT (<u>product number#</u>, product name, selling price, warehouse number#, warehouse address, quantity on hand)

PRODUCT SUPPLIER (<u>product number#</u>, <u>supplier number#</u>, cost price)

SUPPLIER (<u>supplier number#</u>, supplier name, supplier address)

Third Business Normal Form (3BNF):

Identify and remove into another entity those attributes which are dependent on a key other than the primary (or compound) key.

3BNF entities for PRODUCT:

PRODUCT (<u>product number#</u>, product name, selling price, warehouse number#, quantity on hand)

PRODUCT SUPPLIER (<u>product number#</u>, <u>supplier number#</u>, cost price)

SUPPLIER (<u>supplier number#</u>, supplier name, supplier address)

WAREHOUSE (warehouse number#, warehouse address)

Fourth Business Normal Form (4BNF):

An entity is said to be in fourth business normal form when: (1) it is in third business normal form and its attributes depend not only upon the entire primary key, but also on the value of the key; or (2) when an attribute has been relocated from an entity where it is optional to an entity where it is wholly dependent on the key and must exist, and so is mandatory.

4BNF entities for ORDER:

CUSTOMER (<u>customer number#</u>, customer name, customer address, customer account balance, customer credit limit)

PRODUCT (<u>product number#</u>, product name, quantity on hand, quantity on order)

ORDER (<u>order number#</u>, delivery address, order date, customer number#)

ORDER LINE ITEM (<u>order number#</u>, <u>order line number#</u>, agreed sales price, discount percent, product number#)

ORDER LINE ITEM TYPE (<u>order line item type id#</u>, order line item type description)

ORDER LINE ITEM ROLE (<u>order number#</u>, <u>order line number#</u>, <u>order line item type id#</u>)

OUTSTANDING LINE ITEM (<u>order number#</u>, <u>order line number#</u>, product quantity ordered)

BACKORDERED LINE ITEM (<u>order number#</u>, <u>order line number#</u>, quantity on backorder)

SHIPPED LINE ITEM (order number#, order line number#, product quantity shipped, date shipped)

Fifth Business Normal Form (5BNF):

An entity is in fifth business normal form if its dependencies on occurrences of the same entity or entity type have been moved into a structure entity.

5BNF structure entity for PRODUCT:

PRODUCT STRUCTURE (product number#, product type#, sequence#, product number#, product type#, quantity for assembly)

Once the details are captured and verified through normalization, a stable operations data model is generated. The model now contains all data needed for implementation. However, before implementation begins, the information processing requirements must be delineated and this is accomplished through Process Modeling.

D. PROCESS MODELING

Processes, specific procedures that describe the actual data flow throughout an organization, are essential for an effective implementation of the database design as modeled in the strategic, tactical, and operational stages. It is important to note that in IE, processes are defined without regard to any physical means. This differentiates it from the Structured System Design's process modeling which does incorporate physical data flow means. [Ref. 12:p. 181] The idea is to capture the logic of the data flow not the physical means by which it occurs. The question "What is to be done?" must be specifically answered by the users, not "How do you do your job?" [Ref. 19:p. APP 3.4]

Process Modeling is accomplished by:

Specifying Business Events

Business events are things that happen in the environment outside of the system that cause the system to react. The system reaction may be to:

- Record the facts related to the event
- Produce specific products related to the event
- Cause further actions to be taken within the system

Identifying System Functions

System functions are the definition of the system reaction to the occurence of business events. The definition must include:

- Input data requirements
- Output data requirements
- Internal data transformations

Procedure Data Model

Each System Function will be defined as a Procedure, or set of Procedures, which will accomplish the function. These procedures are to be written to express the 'What is to be done,' not the 'How to do it' and should be written in business terms related to the data transformations necessary to accomplish the process.

Specifying Interactive User Interfaces

Interactive User Interfaces are the visual portrayals of the behavior of the system in response to user actions. They include:

- Control Menus
- Data Entry Screens
- Response Screens
- Product Request Screens

Specifying Pre-Planned System Products

System Products include all the various report formats needed to satisfy information requirements for business purposes. They include:

- Pre-specified On-line Screen Reports
- Pre-specified On-line Printer Reports
- Pre-specified Batch Reports

Defining External System Interface Requirements

Specify the information requirements for recurring data transfer to or from other automated systems. This includes new automated interfaces to systems outside the organization, as well as 'refresh' interfaces from existing systems that will be part of the new overall system.

Defining Data Migration Requirements
Specify the information requirements for data loading to initialize the physical database. These are one-time, or seldom used routines that will not be a recurring, regular part of the new overall system. [Ref. 19:p. APP 3.4]

Implementation is dependent upon stable data and process models. The data model provides the necessary data and the process models demonstrate the flow of the data through the organization. The combined results are the functional requirements of the system. Firm functional requirements allow the system to be implemented on a variety of hardware systems. [Ref. 19:p. APP 3.10]

Modeling can be a long (several months), difficult and tedious process. Throughout the process, the opportunity for errors exists. Each management level of an organization views data and information differently. Consequently, insignificant data is often modeled and processes are inaccurately described. The result is an incorrect and possibly ineffective database. Quality control must be exercised in order to ensure the development of a complete and accurate database and will be discussed in the following chapter. Quality control as it relates to the THAIS project will be discussed in the following chapter.

IV. QUALITY CONTROL of the THAIS MODERNIZATION PROJECT

THAIS modernization, like all software projects, is subject to errors. In order to minimize errors, a certain amount of quality control must be exercised throughout the project's life cycle. The difference between a project which fulfills requirements specifications and meets with the user's satisfaction and one which does not is determined by the amount of quality control exercised. Typical problems associated with a management information system design and implementation and which effective quality control can alleviate are:

- Software-naive customers who are usually interested only in software output.
- Poorly defined, but often highly complex, customer objectives.
- A high turnover rate for personnel, resulting in the continual review of existing software and high training costs.
- Externally or internally generated constraints (e.g., cost, time, and manpower limitations)
- Personnel of widely varying levels of skill. [Ref. 21:p. 465]

Before quality control on the THAIS modernization project is discussed it is helpful to describe a framework for evaluating quality control.

A. CRITERIA FOR QUALITY CONTROL

There are many methods for evaluating the quality of a project but each method must emphasize three points:

- Software requirements are the foundation from which

quality is measured. Lack of conformance to requirements is lack of quality.

- Specified standards define a set of development criteria that guide the manner in which software is engineered. If criteria are not followed, lack of quality will almost surely result.

- There is a set of implicit requirements that often goes unmentioned (e.g., the desire for good maintainability). If software conforms to its explicit requirements but fails to meet implicit requirements, software quality is suspect. [Ref. 3:p. 433]

Quality control is affected in three areas. These areas are a product's operational characteristics, a product's ability to undergo change, and a product's adaptability to new environments [Ref. 3:p. 433]. Eleven quality factors have been proposed to help quantify quality control within these three areas. These quality factors are:

- Maintainability (Can I fix it?)
- Flexibility (Can I change it?)
- Testability (Can I test it?)
- Portability (Will I be able to use it on another machine?)
- Reusability (Will I be able to reuse some of the software?)
- Interoperability (Will I be able to interface it with another system?)
- Correctness (Does it do what I want?)
- Reliability (Does it do it accurately all of the time?)
- Efficiency (Will it run on my hardw[illegible] as well as it can?)
- Integrity (Is it secure?)
- Usability (Can I run it?) [Ref. 3:p. 434]

The above factors can be utilized to evaluate the relative quality of a project simply by asking each of the associated questions. In order to ensure a high level of quality throughout a project, these factors should be reviewed constantly. Although they originally were proposed in the context of software quality control, these factors should not

be limited in scope to the physical software design and characteristics. Project management has an equal responsibility with the software development team to provide quality control throughout a project's life cycle.

B. THAIS PROJECT MANAGEMENT QUALITY CONTROL

THAIS management is divivded into two levels. The overall management of the THAIS modernization occurs at NCTC, Washington. The second level is local management at the prototype site, NCTS San Diego and CNSP, San Diego, and at the deputy program manager site, NARDAC Norfolk. [Ref. 22]

1. Overall Project Management Quality Control

At the upper level, quality control involves coordinating and monitoring the funding of the project. Policy is set as to the direction which the project should take when various critical events occur or milestones are reached. Management at this level must focus on the factors which directly affect the long term utilization of the system. These factors are:

- flexibility
- reusability
- interoperability
- portability [Ref. 22]

Flexibility is important because the operational environment of the system is dynamic and future contingencies must be accounted for. Reusability is an increasingly important factor since monetary constraints drive the need to cut costs wherever possible. Reusability directly leads to a savings in time which leads to monetary savings. Upper level

management must also be concerned with interoperability since the possibility exists to couple this system to systems already in existence or future systems. THAIS is expected to be interoperble with the Operational Support System (OSS) which runs on SUN 4300 machines, the SNAP III system which is still under development, and the Maintenance Resource Management System (MRMS) [Ref. 22]. Portability must be sought in order to ensure utilization on several different hardware configurations since there is no standard hardware system at the Type Command level and below. At a recent program review, a THAIS submodule was demonstrated on a Zenith Z-248, a COMPAQ PC, a UNISYS 386, and a Zenith laptop PC to ensure portability. The submodule worked effectively on each system. [Ref. 22]

Quality control at this upper level is monitored primarily through program reviews. Direction of the project must be reaffirmed to the Prototype site and the Central Design Activity (CDA), NARDAC Norfolk, who must then ensure that all quality factors are satisfied. In order to closely monitor the quality control, NCTC also receives monthly status reports from the CDA and conducts quarterly reviews at the CDA.

2. Quality Control at the Type Command Level

Management at the prototype site is concerned with operational characteristics. The quality factors associated with these characteristics are:

- maintainability
- testability
- flexibility
- correctness
- reliability
- efficiency
- integrity
- usability

Assurance of maintainability at this level is important because of the requirement to be able to correct and upkeep the software code. Type Commands do not possess the funds and personnel to support a large maintenance effort on THAIS. This drives the need to ensure that the maintenance required is capable of being completed.

The reasons for the importance of testability are similar to those of maintainability. Type Commands strongly desire a proven system, one that has been tested on site. Ensuring testability means ensuring that system tests can be completed within available Type Command funding limitations and assigned personnel.

As with upper management, the flexibility to change a program is a necessary function within THAIS because dynamic situations under the cognizance of Type Commands require continual adaptation by management. Type Commands are the experts on their mission objectives and are the best personnel to monitor the correctness of the system. The ability of the system to reliably perform for an extended period must also be monitored at the Type Command level. Since they will be the users and will not want to operate a system which is consistently inefficient and unreliable, Type Commands serve as the

best judges of system efficiency and reliability. Data security is another factor which is best monitored at the Type Command level since they know the security requirements and the consequences of violating those requirements. Finally, the usability of the system can only be monitored at this level because the system is used at this level. Outside software developers do not sufficiently anticipate the ability of personnel unfamiliar with the system, primarily due to high turnover rates, to use and become proficient with the system.

Quality control is performed at the Type Command level by constant interaction between the IE development team and the Type Command personnel assigned at the prototype site. This team is responsible for ensuring the accuracy of the data and its relationships as well as guiding the prototype site personnel in the proper direction for modeling the organizational data.

C. THAIS PROJECT DEVELOPMENT QUALITY CONTROL

The assurance of quality control within the physical development of the system is accomplished by the design software itself, IESC's *USER: Expert Systems*. Improper entity, attribute and association relationships are automatically detected and provided to the user in report format upon request using the *USER: Project* module. The errors are then manually corrected, ensuring an accurate database. [Ref. 23]

The user only becomes aware of errors if he specifically requests a report. This is inadequate since much design work may be completed based on faulty data relationships. The work would have to be completed again with the correct information thereby delaying the design process. One feature of the software which exposes errors is the data mapping module, *USER: Plotmaster*. This module will not map incorrect data relationships. Unfortunately, this is the only module which does not tolerate errors. [Ref. 23]

D. SUMMARY

Ensuring a high quality product is a constant process of monitoring the activities of the project management and the project development teams. Without continual attention, the product will be less likely to meet user requirements and therefore be unsatisfactory. Although IESC's software requires additional error detection capabilities during the actual data entry phase, the IE process is well suited for conducting quality control. The typical problems associated with management information system design and implementation are listed below. The close interaction between management and development teams which the IE methodology espouses can overcome these problems.

The quality factors described earlier can be sufficiently provided for within the framework of IE. This methodology is centered on an organization's data and involves the user and

management to a high degree in the design process. With these characteristics, all eleven quality factors can be accomodated during the IE process thereby ensuring high customer satisfaction. Also, effective use of CASE tools speeds system development, thereby enhancing quality in that the developer is able to commit more time to requirements analysis and system design. The following table represents the projected savings resulting from the use of CASE tools [Ref. 24:p. 150].

THE ADVANTAGES OF AUTOMATION

Program size	Projected savings with CASE* compared with current methods		
	Cost	**Time**	**Staffing**
SMALL	95%	97%	0%
MEDIUM	94	92	50
LARGE	92	83	88
VERY LARGE	87	80	37

Table 1 Advantages of CASE Technology
*Computer–Aided Software Engineering

The stable information systems architecture produced from IE is, in itself, a form of quality control. It ensures that an organization, such as a Type Command which has several dispersed and specialized functional areas, is able to sharply focus on its organizational goals. Unfortunately, there are

factors which detract from the quality control benefits of IE and which render IE an insufficient methodology as practiced on the THAIS modernization project. The benefits and problems associated with IE on the THAIS project are discussed in the following chapter.

V. RESULTS of CNSP IE EFFORTS

The THAIS system represents a very good example of the need for IE during system design and implementation. Type Commands work with large volumes of data from many different functional areas, with much of the data redundant or irrevelent. They also use several management information systems which ideally should be integrated into a single, relational database management system. IE is a methodology which was designed to rectify this situation and was utilized on the THAIS redesign for this reason.

The utilization of IE during the redesign project had several benefits. IE allowed an organization such as CNSP to develop a stable information systems architecture. This stable foundation will enable the organization to change its policies and objectives without attention to redesigning its information system. Involvement with data modeling at the strategic and tactical levels was very helpful in determining the basis for a useful database design. Essential, relatively constant data, independent of processes that may change, were captured for use in the database design. Also, intensive management and user involvement ensured that the data was complete and accurate. This involvement provided a better understanding of the organization and its purpose throughout CNSP's distinct functional areas. However, there were several

difficulties experienced with IE during the THAIS modernization project.

A. REASONS for DISSATISFACTION with IESC's IE

There are several corporations which specialize in IE with only minor variations in their interpretations of the methodology. IESC was chosen as the contractor for the THAIS modernization therefore their methodology and their CASE tool, *USER: Expert Systems*, was utilized.

IESC was contracted to design a database using IE to identify CNSP's strategic objectives and operational requirements during a nine month time-frame from January to September 1990. IESC assigned two full-time representatives or consultants to the THAIS project. These men worked with CNSP staff and NCTS San Diego personnel to map CNSP's information requirements through strategic, tactical, operational and process modeling. Prior to each modeling stage, a one week workshop was held to introduce and familiarize the participating personnel with the goals and details of each modeling stage. The workshops included personnel from other Type Commands, specifically from COMSUBPAC, Pearl Harbor and CNSL, Norfolk. Other Type Commands were expected but unable to attend. Representation from several Type Commands was desired in order to facilitate designing a system which would satisfy the requirements of all Type Commands and not be unique to an individual Type Command. For clarification, a Type Command is

an organization which controls a specific group of assets which are surface forces, air forces, and submarine forces. Each Type Command has equivalent or similar functional areas and information requirements. Input from each Type Command is necessary to more accurately map information requirements and design a more useful system.

Strategic, Tactical and Operational modeling proceeded smoothly but at an unexpectedly slow pace [Ref 16:p. 1]. The

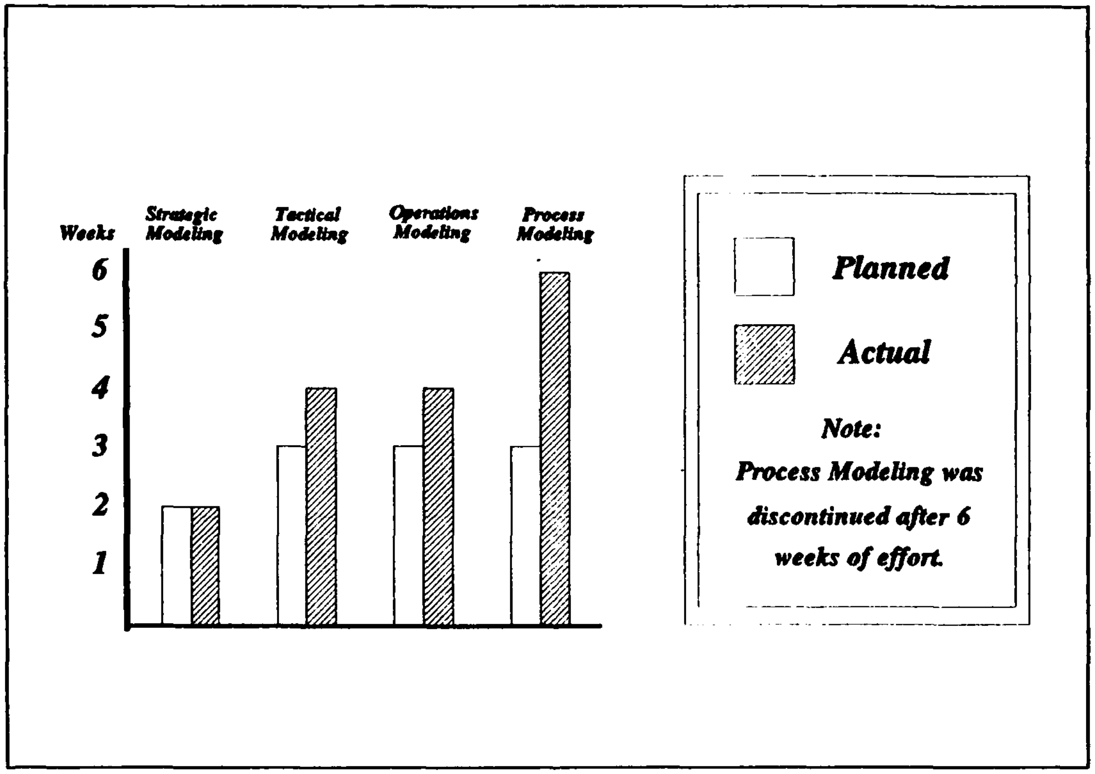

Figure 13 Data Modeling Progress [Ref. 16:pp. 1-2]

slow pace can be attributed to several factors. First, data modeling was not treated as a full-time effort [Ref. 16:p. 1]. Personnel from CNSP staff, the primary project ´experts´ on the organizational data and data relationships, were committed

to their primary duties and often unavailable to provide critical input. Also, the requirement for and procedures of many data and information flows had to be verified in CNSP and higher chain of command documents during the modeling process which led to significant time delays. In most situations the procedures and data requirements were nearly identical across Type Commands but a few situations existed where there were variations. These situations dictated the need to standardize the dissimilar procedures which incurred unexpected delays. Finally, data modeling proved to be a difficult and tedious process, especially the identification of entities and their associated normalization.

According to Clive Finkelstein, the founder of IESC, an IE project should have between 10-20 entities per tactical model with approximately 20 tactical models per strategic model and an entity/attribute ratio of 1:5 at the tactical level. The strategic model should have 250-750 entities [Ref 2:p. 246]. The Readiness Reporting Module, the second of seven tactical areas to be modeled in the THAIS project, contained 299 entities and 478 attributes for an entity/attribute ratio of 3:5 [Ref. 25:pp. 41,77]. These figures are significantly higher than the expected number for a typical IE project for two reasons. First, the project was not typical in that the scope of the project was much larger than expected by IESC. Second, the data was normalized to an unmanageable level which created an excessive number of entities and attributes.

According to the James Martin Associates Corporation, a very respected IE firm, "...a project with that many entities in one tactical area is a recipe for failure." [Ref. 26]

The difficulty with such a large number of entities and attributes begins with the normalization. Theoretically, N^{th} normal form is the ultimate in normalized data. Generally, higher normalized forms of data dictate more storage space and increased access time, two undesirable traits, but incur more flexibility within a relational structure. [Ref. 20:p. 1]

> As the same atomic data is represented by more relations, additional keyed fields are required within each relation to perform the joins necessary for data access. This has the effect of greatly increasing the data storage requirements and therefore the data transfer times.
>
> As additional relations are created, each relation requires at least one more disk access to retrieve data along with a keyed search to determine the data location (which itself may be much greater than one access). [Ref. 20:p. 2]

IESC's approach in the THAIS project was to normalize the data to fifth normal form (5NF). This form is significantly higher than the typical third normal form (3NF) used on many projects. Although 5NF provides a major increase in the flexibility of a system and is capable of being done, it is not practical. An example of this added flexibility within THAIS is illustrated with the following comparison. The entity 'CASREP' has four attributes: CASREP Age; CASREP Number; CASREP Total Requisitions; and Job Sequence Number. The entity 'CASREP Message' has only one attribute, CASREP Message Serial Number. Access to the former entity requires retrieval of all four attributes but access to the second

entity requires retrieval of only one attribute. The one-to-one entity/attribute characteristic of 'CASREP Message' allows a greater degree of flexibility within the relational structure. However, the effort required to get to the 5NF of 'CASREP Message' and the added storage, time and money requirements do not justify the additional flexibility over 3NF. In addition, all of the data modeled during the IE sessions and normalized to 5NF was subsequently reverted to approximately 3NF when the software developers at NCTS San Diego and Idaho National Engineering Laboratories (INEL) were unable to sufficiently generate code for a relational database in 5NF [Ref. 16:p. 3].

Another problem associated with the IE effort was in the team size assigned to the project. Two full-time consultants and five full-time users comprised the team [Ref. 27]. Although this team size falls within the guidelines set forth by Clive Finkelstein of no more than six users or managers per project team, the team did not consistently operate together [Ref. 2:p. 263]. The two consultants often split their time with the group and the users often entered and departed the modeling sessions irregularly as their additional duties required.

Process modeling proved to be a major problem with the IE portion of the THAIS project. This phase requires the completion of the following tasks:

- Determine the business processes associated with the stable Operations Data Model.

- Design screen forms and reports based on the stable Operations Data Model.

- Document the procedures necessary to accomplish business procedures.

- Produce design documentation for implementation in a variety of languages and DBMS products. [Ref. 28:p. vi]

These tasks were not completed for several reasons. The project up to the process modeling stage went smoothly, but this stage of the project became burdensome causing the project to fall behind schedule. According to one team member, this phase "...has proven to be the most confusing, labor intensive, and difficult phase." [Ref. 16:p. 1] The reasons for falling behind schedule and the difficulty experienced by the team members can be attributed to the following factors as delineated by the CNSP Special Project Officer, Capt. Shillingsburg:

- Failure by the contractor to communicate the difficulty of this phase. Many of the 'users' were led to believe the modeling would be completed in three weeks.

- Failure of the contractor to provide experienced facilitators during process modeling resulted in confusing and poor guidance on how to proceed and what was required.

- A software problem in the IESC tool resulted in the 'users' working several weeks with out-of-date reports and also reduced IESC support to the 'users' as the contractor devoted considerable time trying to resolve the software problem.

- Process modeling is complicated and a skill that cannot be learned in one week.

- The CASE tool used by IESC supports the Strategic, Tactical, and Operational modeling phases but does not support the Process modeling phase. [Ref. 16:p. 2]

Process modeling was considered a failure after approximately six weeks of effort. A great deal of the difficulty resulted from a lack of organization and a lack of knowledge on the IESC consultants' part [Ref. 29:p. 1]. As acknowledged by an IESC representative, IESC has not had great success with process modeling on other projects and the large size of the THAIS project made process modeling especially difficult [Ref. 29:p. 1].

As a result of the problems identified above, CNSP became dissatisfied with IE. The inability of the software developers to utilize the data modeled through IE was itself enough evidence against IE and IESC to not renew IESC's contract for additional THAIS modules and to continue the project under the direction of the software developer, INEL.

B. INTRODUCTION OF INEL's SAGE METHODOLOGY

As a THAIS modernization milestone approached, the delivery of the first module within the Readiness Reporting functional area, the CASREP module, in September 1990, the project was behind schedule [Ref. 16:p. 2]. The software developers were supposed to receive the final database design from IESC in the June/July timeframe. However, the design was not delivered until early August. INEL, which was tasked by NCTC with using ADA to develop the software, reviewed the design and found it unsatisfactory and incompatible with their SAGE development methodology.

The primary issue was the normalization of the data to 5NF. INEL discovered that the 5NF was too detailed for use with their ADASAGE software package which created several problems during implementation. The problems discussed earlier with 5NF and the additional problem of the inability of DOS to handle large access times required the database to be redesigned in 3NF. [Ref. 30]

INEL found the documentation of the delivered database design to be inadequate. Therefore, several functional experts from CNSP and NCTS San Diego were required to work with INEL during the early stages of software development to provide explanations of the data elements [Ref. 30]. Although INEL faced several problems with the IE designed database, it was quite pleased with the completeness of the data elements. This enabled the software development to proceed rapidly, approximately six weeks from start to completion of the first prototype [Ref. 30].

One final problem which INEL had to solve during software development was the lack of hardware consideration during the database design. Although hardware is not considered an important aspect during the IE process, in fact it is deliberately disregarded, the SAGE software development methodology requires its consideration. Therefore, INEL had to analyze the hardware requirements and alter the database design to fit those requirements. This alteration was primarily the denormalization of the data to 3NF in order to solve the

access time limitations within DOS since DOS was the operating system of choice on the THAIS PC platforms. [Ref. 30]

C. BENEFITS OF INEL's SAGE METHODOLOGY

INEL's SAGE software development methodology was introduced in Chapter II. This methodology provides a rapid prototyping approach which allows the completion of an initial prototype in a few weeks. After review and additional inputs from users, subsequent iterations take from a few days to a few weeks to produce depending on the complexity of the additional enhancements [Ref. 31].

The initial THAIS prototype was demonstrated on 30 September 1990. Several iterations have since been produced and the users are still recommending changes to the software. However, the continual user involvement and subsequent fine-tuning of the prototype is a significant problem. Many times the prototype:

- might not include all aspects of the intended system.
- might have been implemented using resources that will not be available in the actual operating environment.
- might not be able to handle the full workload of the intended system. [Ref. 32:p. 13]

Fortunately, the THAIS prototype has been revised to ensure compliance with user and hardware requirements. User refinements could continue indefinately but a deadline of 31 March 1991 has been set for all further refinements. This will be the baseline model for the CASREP module. [Ref. 31]

INEL is working with NARDAC Norfolk and NCTS San Diego on two additional functional areas. Both organizations are learning to use the ADASAGE library and to utilize the SAGE methodology. INEL is providing personnel in training and expert support roles to work with NARDAC Norfolk in developing the Aviation Maintenance area and with NCTS San Diego in developing the Readiness Reporting area. The goal is to be independent from INEL at the end of fiscal year 91 in order to develop future modules totally in-house and to allow the Naval Air Forces Atlantic and Pacific and the Naval Surface Forces Atlantic and Pacific to become independent of the Honeywell DPS-6 minicomputers by September 91. [Ref. 31]

INEL's methodology has proven to be very effective in the development of the THAIS module. CNSP's satisfaction with the methodology and INEL's development efforts have given support to SAGE. The success of the prototype was not totally dependent on SAGE; the IE effort in modeling the data was essential as well.

There are several advantages of IE which were discussed in Chapter II. The advantages of the SAGE methodology were discussed in Chapter II also. Although both efforts were independent, they required some interdependence. The output of IE, the database design, was the input to the software development. CNSP's stated lessons learned from the involvement of both techniques are:

- A small experienced professional team of ADA programmers with good tools can turn out applications in 60-90 days.

- Rapid prototyping should start much earlier in the Information Engineering (IE) cycle essentially replacing the operational and processing phases.

- Active, articulate functional user involvement is essential to success.

- Rapid prototyping dramatically increases user ability to articulate needs which can be translated to software. [Ref. 33:pp. 3-4]

These lessons learned are valid and useful in the evaluation of the project but they pertain to rapid prototyping almost exclusively. However, the justification for using IE must be emphasized.

Although CNSP's dissatisfaction with IE is stated explicitly in Reference 16, IE is a methodology which can be very useful to future DON projects. Its ability to effectively map organizational data and to establish a stable architecture which supports user requirements is exceptional. If used in conjunction with a Rapid Prototyping software development methodology such as SAGE, user satisfaction with the software and project management's satisfaction with overall project completion should improve dramatically over conventional database design and software development techniques.

VI. CONCLUSION and RECOMMENDATIONS

The IE effort on the THAIS modernization project has had a significant impact on the development of database systems for the U.S. Navy. The effort has given upper level management a strategic information systems planning methodology which is more appropriate to the development of a stable information systems architecture than more traditional approaches. Type Commands such as CNSP have been overwhelmed by information requirements of upper management and inundated with data from several distinct functional areas under their control. CNSP's effort in utilizing IE to identify these typical Type Command requirements and to define essential data has resulted in a successful information systems architecture. This architecture should remain stable for many years and provide the basis from which the organization can adapt to changing requirements.

Although problems with the IE contractor tainted the outlook for IE utilization on THAIS modules yet to be redesigned, the benefits from using IE are substantial. The specific benefits are:

- Comprehensive involvement at the upper, middle and lower organization levels ensures complete and accurate data.
- User involvement throughout the design process instills a sense of ownership which favors delivery of a system that will not go unused do to lack of user friendliness or lack of understanding of the system's capabilities.

- Strategic focus on policies and objectives which enables the design of a system more responsive to a changing environment.

- Concentration is on capturing organizational data and establishing a stable information systems architecture instead of designing a system to fit specific hardware.

- Utilization of CASE tools automates the design process and allows project personnel to concentrate their efforts on requirements analysis and data refinement which speeds the design process and increases the quality of the end product.

Although CNSP's efforts resulted in establishing IE as a viable planning and design methodology for use on other DON projects, the effort was not without its pitfalls. Several problems existed in the actual IE process which delayed the delivery of the database design to the software developer. The contractor, IESC, was behind schedule for a large portion of the project due to difficulties with process modeling. This stage proved to be the most difficult and time-consuming portion of the whole project. Inadequate preparation of IESC's consultants during this stage and the inherent difficulty of conducting process modeling caused the project to fall behind schedule. Also, the CASE tool used, IESC's *USER: Expert Systems*, did not support process modeling. The delivery of the database design to the software developer entailed problems as well. The software developer, tasked with delivering a usable system coded in ADA, could not utilize the database design in the form which IESC delivered it. INEL determined the design to be too detailed for its software package, ADASAGE, and consequently had to denormalize

the data to approximately 3NF in order to properly implement the design. INEL used its SAGE software development methodology, which incorporates Rapid Prototyping, to deliver a usable prototype in just six weeks.

The problems associated with IE resulted in CNSP's dissatisfaction with the methodology. Unfortunately, IE's benefits seem to have been overshadowed. IE, as demonstrated by the THAIS modernization, is a valuable tool for planning and designing a large database system which will remain stable for many years. INEL's delivery of the software prototype in just six weeks while utilizing ADA and Rapid Prototyping also demonstrates a useful development process. A technique which would benefit DON the most in future design efforts similar to THAIS would be to utilize IE and SAGE in conjunction with each other. Specifically:

- The IE portion should utilize strategic and tactical data modeling to develop the database design.

- The IE methodology utilized should have a fully capable CASE tool to complete the "front end" effort. IESC's *USER:Expert Systems* does provide this support but it fails to provide adequate code generation or "back end" support.

- The software development portion should utilize a Rapid Prototyping technique to improve the product delivery time and to involve the user continually in order to instill a sense of ownership and create a very usable system.

- The contractors involved in future projects should possess the proper CASE tools and provide adequate support and training to the DON users involved in the design process in order to eliminate the problems encountered by CNSP during process modeling.

This paper has presented an evaluation of CNSP's efforts in the redesign of THAIS. The history and background of both

THAIS and IE were discussed. Problems encountered during the project were exposed and remedies suggested. The THAIS redesign project was successful in that a methodology, IE, which seeks to establish a stable information systems architecture for a dynamic organization such as a Type Command was utilized. The need for this stable architecture is essential in order to prevent ad hoc responses to long term problems which is frequently the situation.

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